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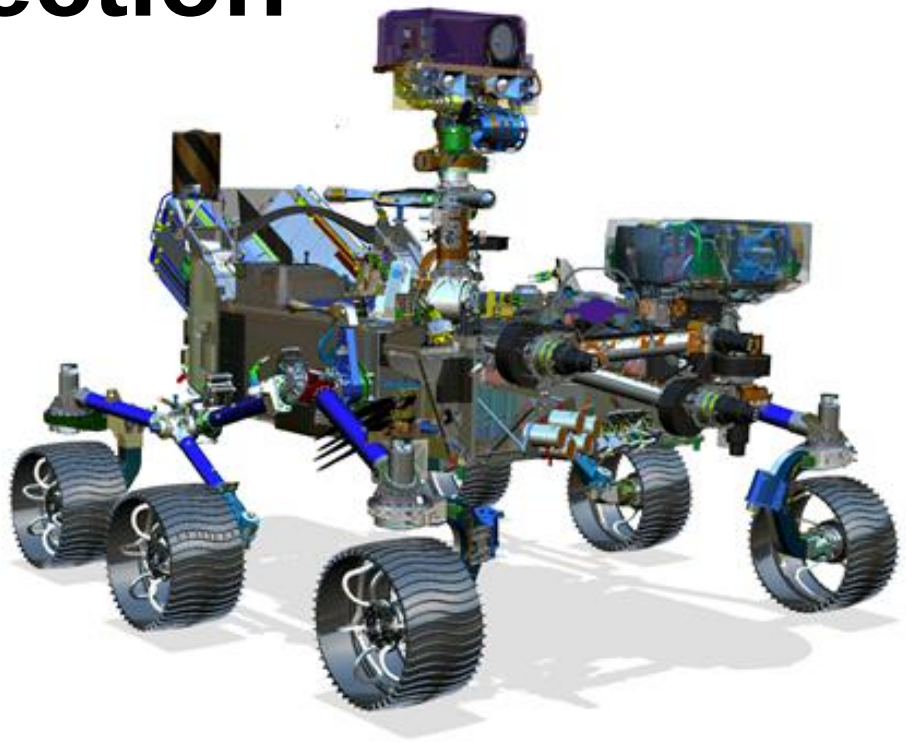
Mars 2020 Mission Overview and the Importance of Planetary Protection



Dr. Moogega Stricker
Mars 2020 Planetary Protection Lead

February 20, 2017

2017 Winter Meeting - American Association of Physics Teachers

History of Rover In-situ science

abrasion + bulk geochemistry

Spirit/Opportunity, 2004

powder drilling + bulk geochemistry

Curiosity, 2012

Sojourner, 1997

Bulk Chemistry. No Sampling.

Source: NASA/The Atlantic

Mars 2020 Overview

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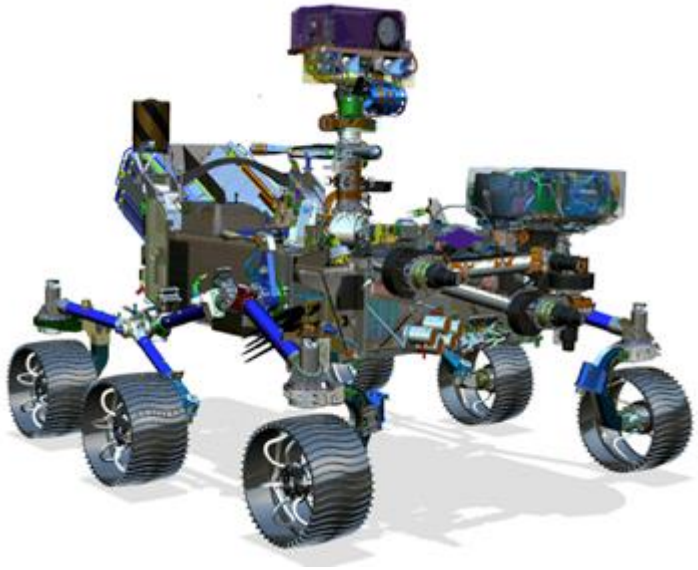
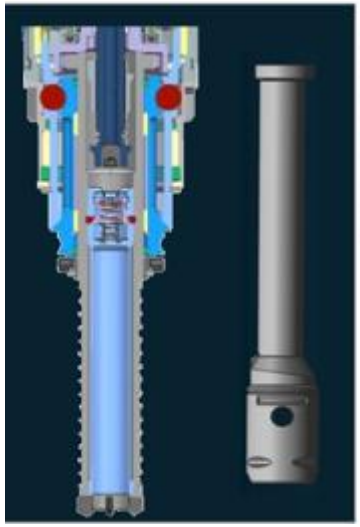
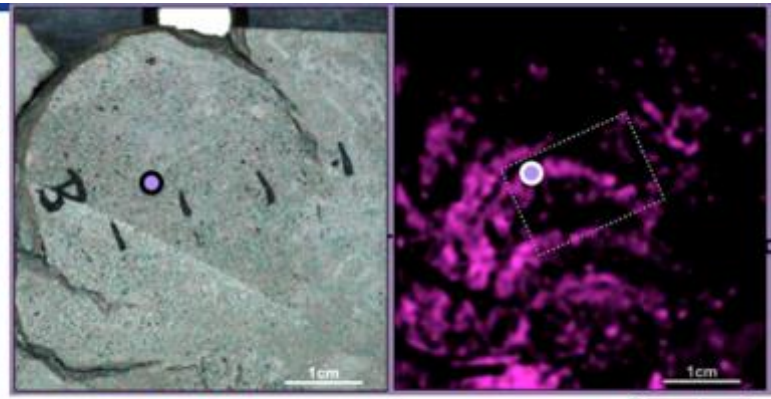
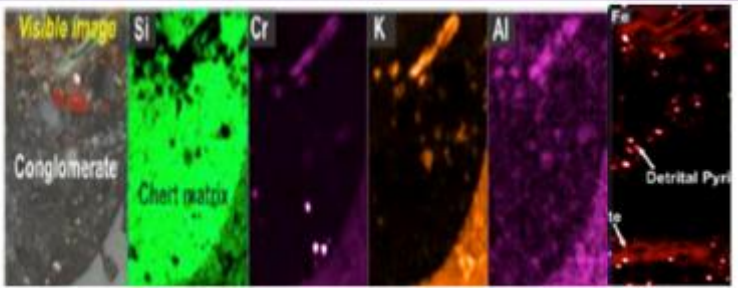
Mars 2020 Project









Science

- *Assess past habitability of an astrobiologically relevant ancient environment on Mars*
- *Assess biosignature preservation potential with the environment and search for biosignatures*
- *Assemble cached samples for possible future return to Earth*

Technology

- *Advance technologies with applications to future human and robotic explorations objectives*

Source:Mars John McNamee and Ken Farley. 2020 Project Mars Exploration Program Advisory Group. March 3, 2016.

Mission Overview

LAUNCH

- Atlas V 541 vehicle
- Launch Readiness Date: July 2020
- Launch window: July/August 2020

CRUISE/APPROACH

- ~7 month cruise
- Arrive Feb 2021

ENTRY, DESCENT & LANDING

- MSL EDL system (+ Range Trigger and Terrain Relative Navigation): guided entry and powered descent/Sky Crane
- 16 x 14 km landing ellipse (range trigger baselined)
- Access to landing sites ±30° latitude, ≤ -0.5 km elevation
- Curiosity-class Rover

SURFACE MISSION

- 20 km traverse distance capability
- Enhanced surface productivity
- Qualified to 1.5 Martian year lifetime
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

How Hard is it to land on Mars?

http://www.jpl.nasa.gov/video/details.php?id=1087
(removed for URS submission. Too large to attach)

EDL Timeline

Now with 100% more TRN!

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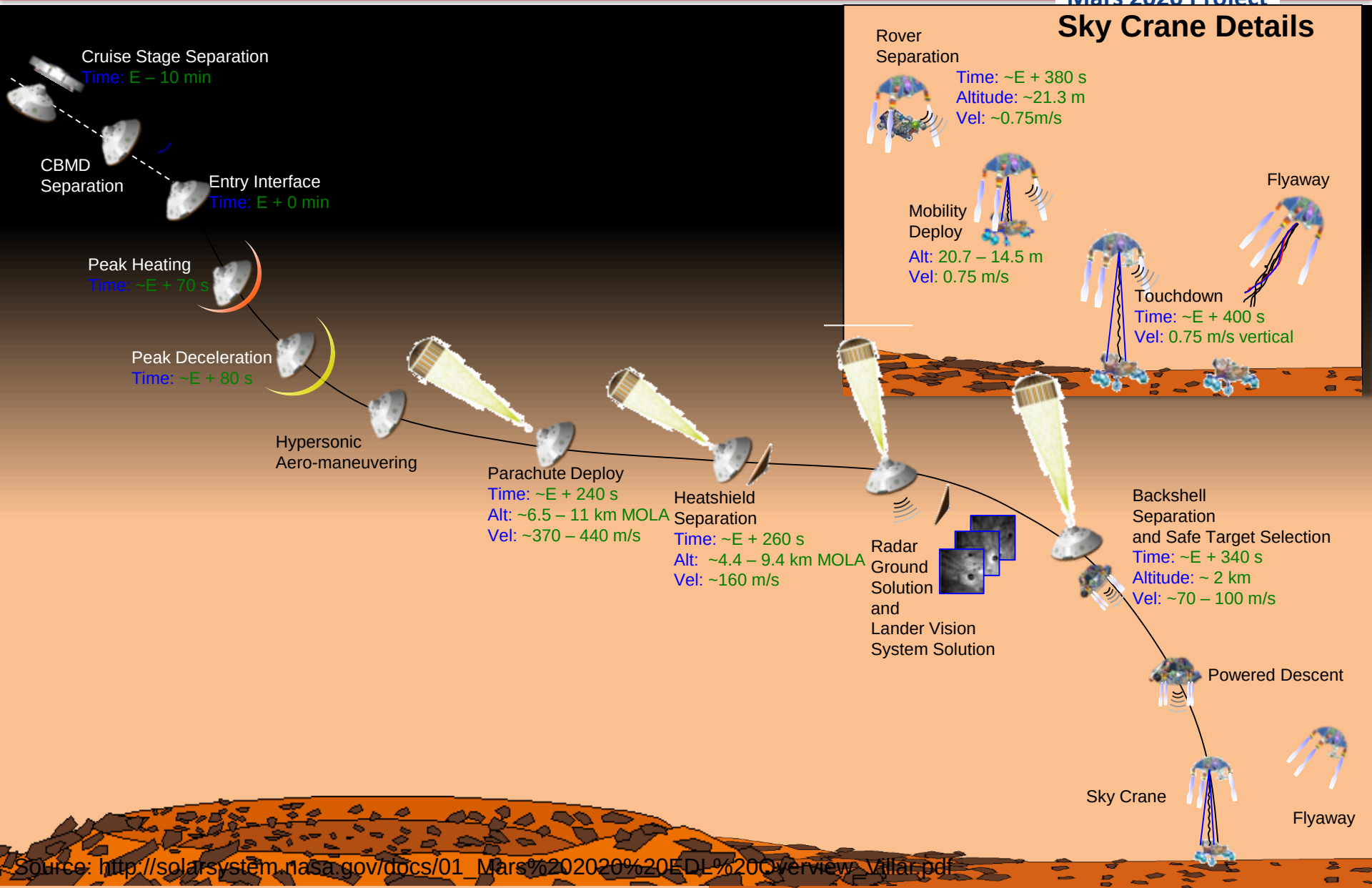


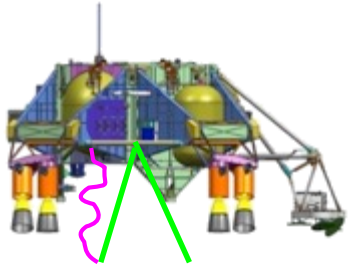
Source: http://solarsystem.nasa.gov/docs/01_Mars%202020%20EDL%20Overview_Villar.pdf

Spacecraft Build Approach

Launch Vehicle

- Cruise Stage
- Built in-house at JPL

- Bachskell
- Built by Lockheed-Martin/Denver



- Descent Stage
- Built in-house at JPL

MMRTG

Science & Exploration Technology Investigations

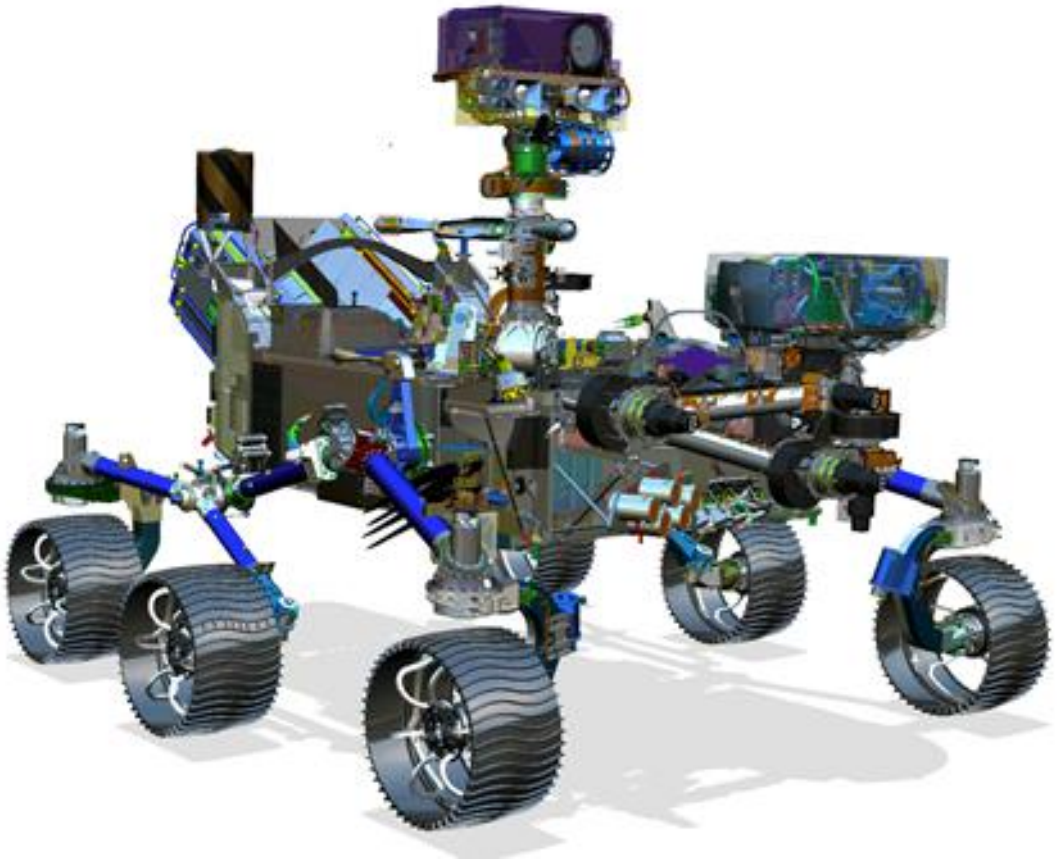
- Rover
- Built in-house at JPL
- Major industry subcontracts/components
- Spanish contributed High Gain Antenna

MEDLI2

- Heat Shield
- Built by Lockheed-Martin/Denver

Mars 2020 Rover Concept

Mars2020 Rover is a combination of Heritage, Modified & New



- ❑ Thermal HW
- ❑ Sampling and Caching System – all new
- ❑ Motor Control System
- ❑ Rover Mechanical
  - ❑ Rover Chassis
  - ❑ Rover Mobility
  - ❑ RSM
  - ❑ Harness
- ❑ Avionics (Rover Compute Element)
- ❑ Power Hardware
- ❑ Telecom & Guidance and Nav and Control Hardware HW
- ❑ Science Instruments
- ❑ Enhanced Engineering Cameras (EECAM) (Haz/Nav)
- ❑ EDL Camera electronics
- ❑ Vision Compute Element (VCE)
- ❑ Landing Camera

Mars 2020 Mission Objectives

Conduct Rigorous *In Situ* Science

A. **Geologic Context and History** Carry out an integrated set of context, contact, and spatially-coordinated measurements to characterize the geology of the landing site

B. **In Situ Astrobiology** Using the geologic context as a foundation, find and characterize **ancient** habitable environments, identify rocks with the highest chance of preserving **signs** of **ancient** Martian life if it were present, and within those environments, seek the signs of life

Enable the Future

C. **Sample Return** Assemble rigorously documented and returnable cached samples for possible return to Earth

D. **Human Exploration** Facilitate planning for future human exploration by making significant progress towards filling major strategic knowledge gaps and…

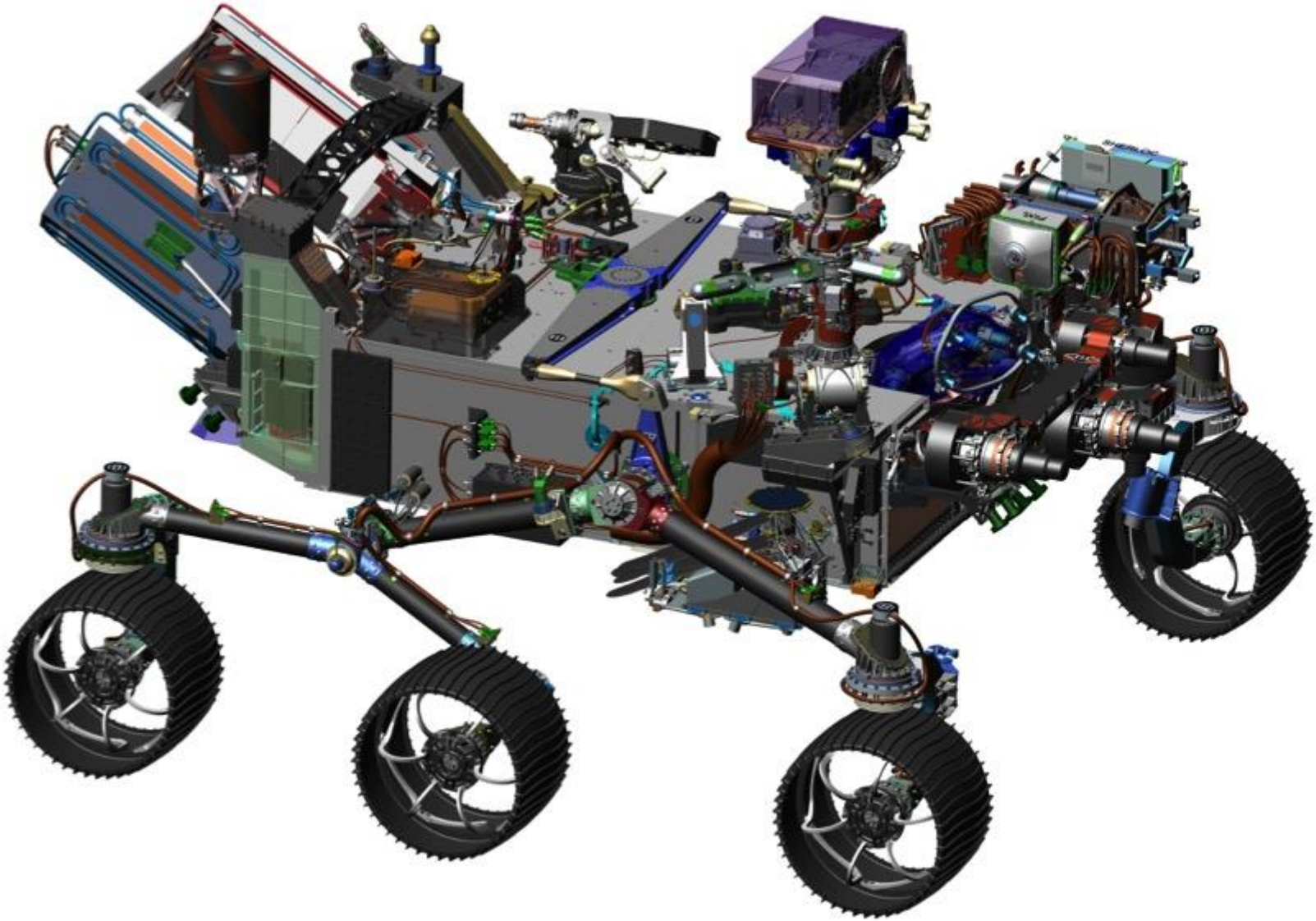
Technology …demonstrate technology required for future Mars exploration

Execute Within Current Financial Realities

– Utilize MSL-heritage design and a moderate instrument suite to stay within the resource constraints specified by NASA

These are a thoroughly integrated set of objectives to support Agency's Journey to Mars

Mars 2020 Rover



Mars 2020 Payload Family Picture

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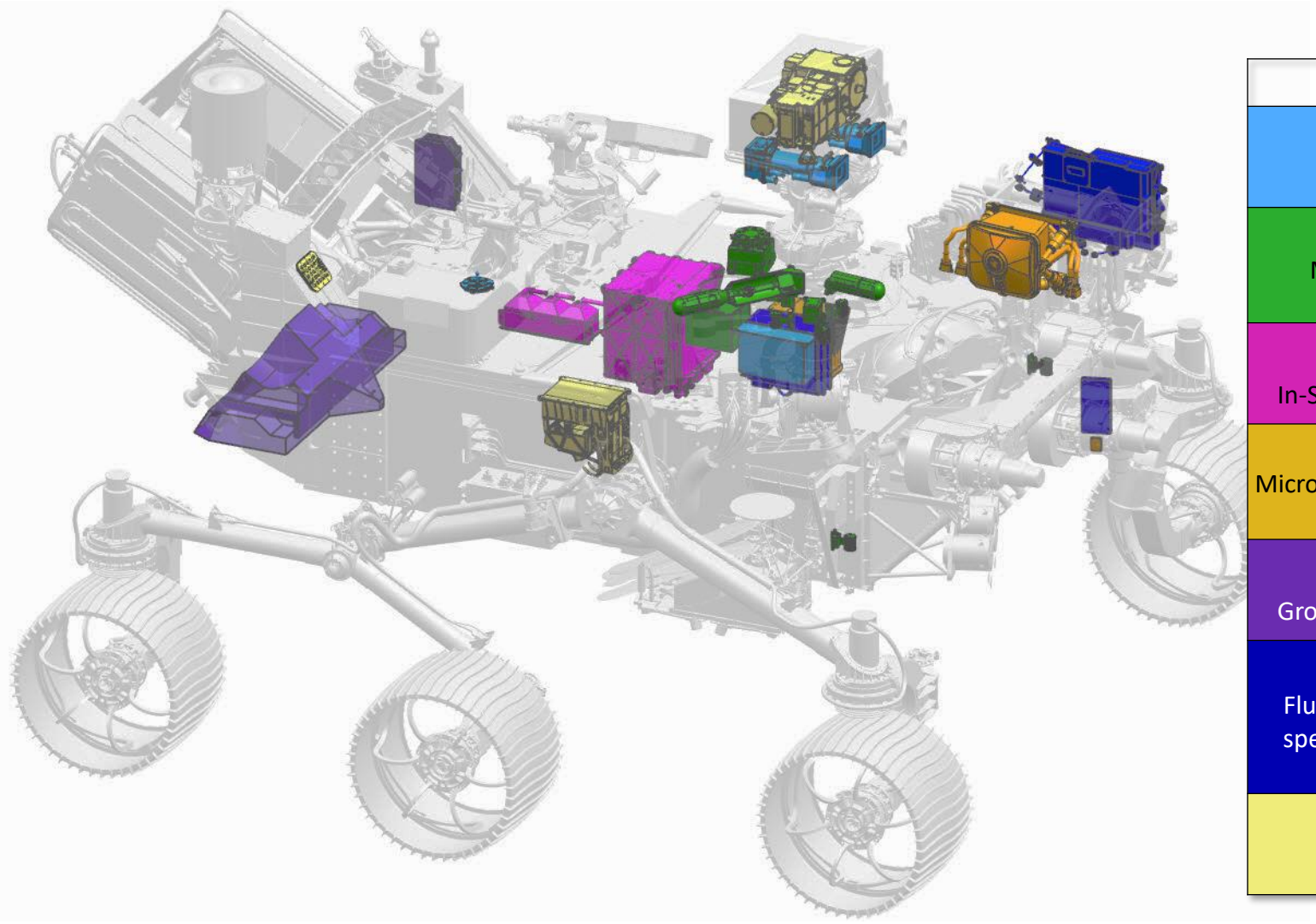
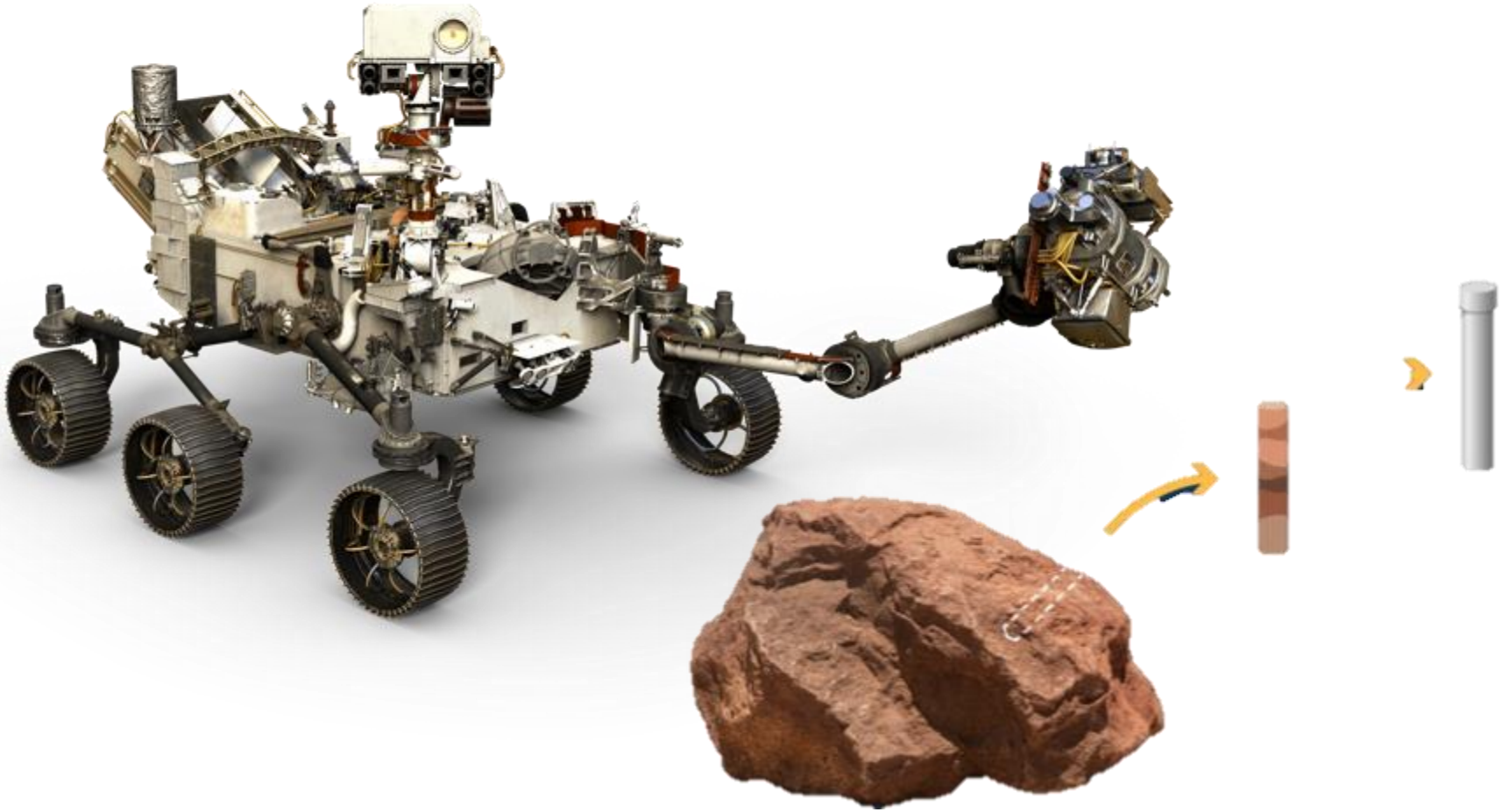


Instrument Key
Mastcam-Z Stereo Imager
MEDA Mars Environmental Measurement
MOXIE In-Situ Oxygen Production
PIXL Microfocus X-ray fluorescence spectrometer
RIMFAX Ground Penetrating Radar
SHERLOC Fluorescence and Raman spectrometer and Visible context imaging
SuperCam LIBS and Raman

Sampling and Caching System Hardware



Source: NASA

Tube drop-off occurs throughout the Mission

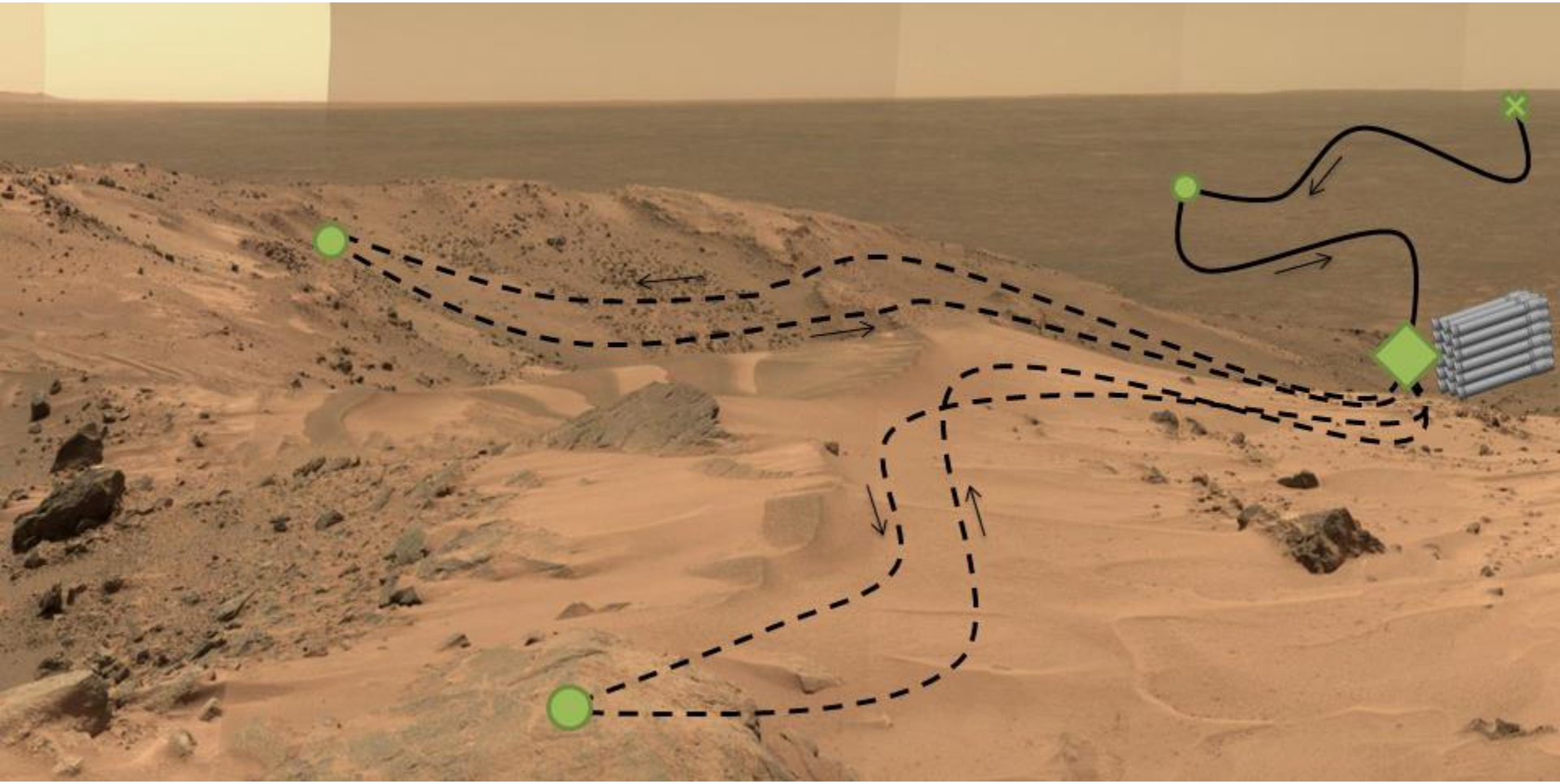


Image Credit: NASA/JPL-Caltech/Cornell Univ./Arizona State Univ.

Mars 2020: First leg of *potential* Sample Return

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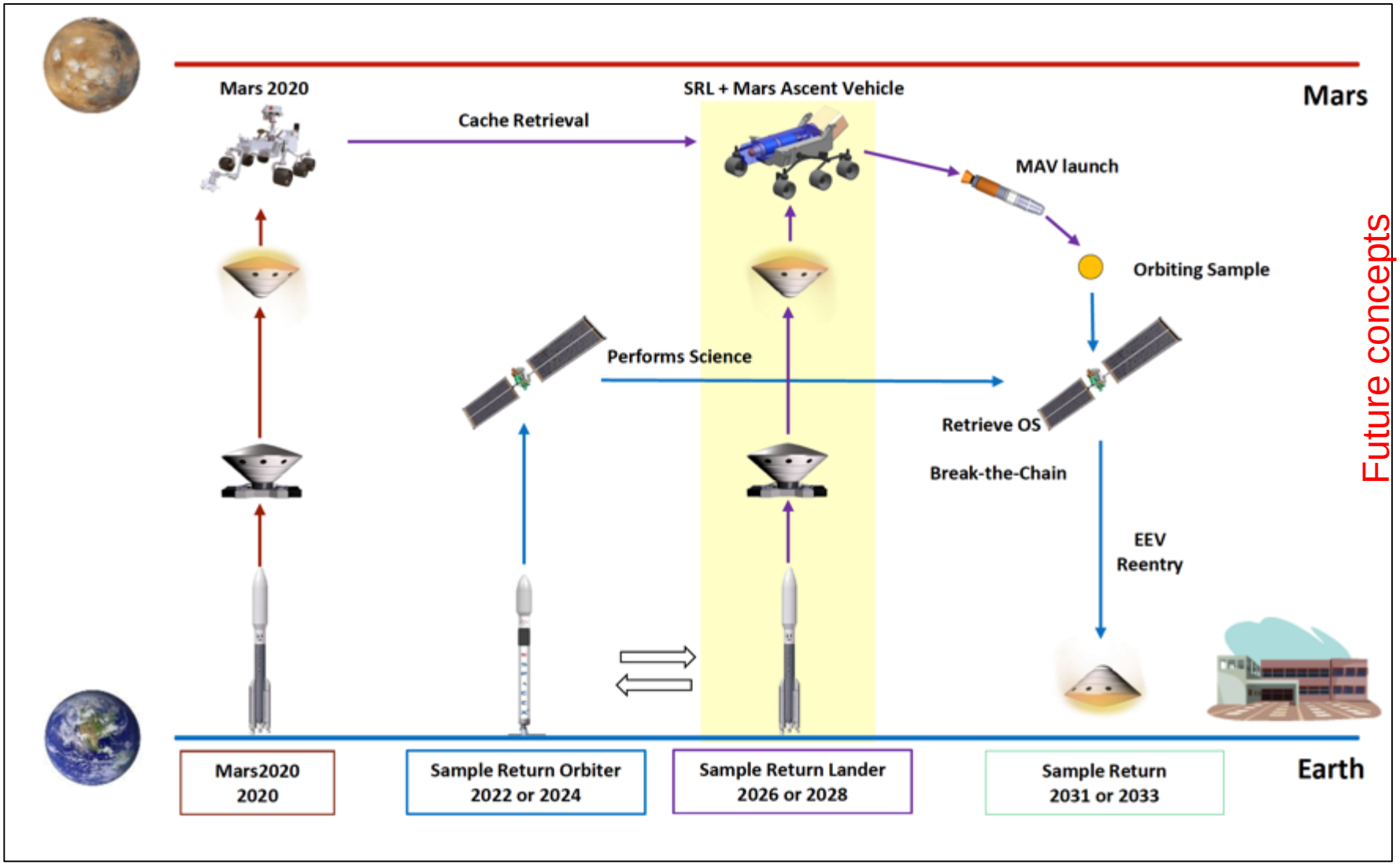
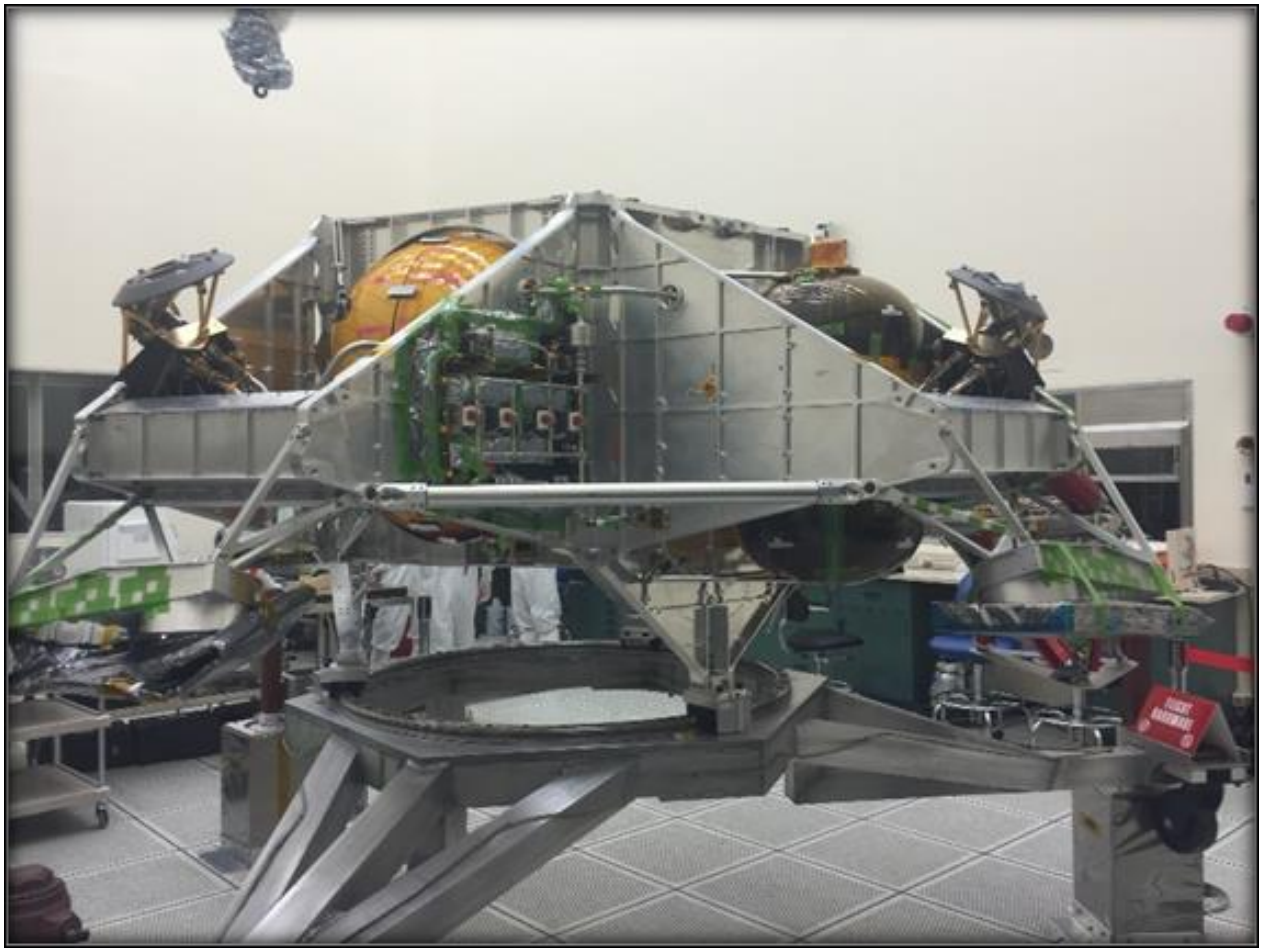
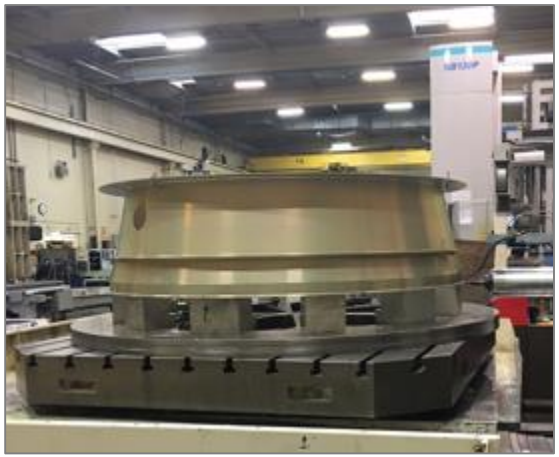


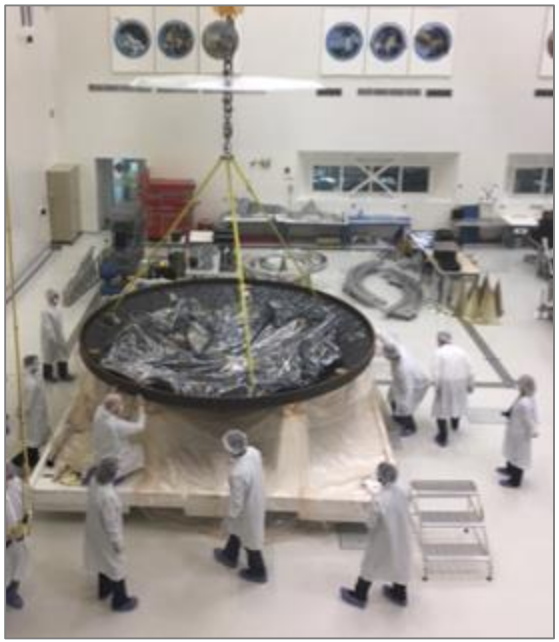
Pre-decisional: for information and discussion only.

Austin Nicholas, "Landing Site Considerations Related to the Potential Sample Retrieval and Launch Mission". August 4, 2015.

Mars 2020 Cruise / EDL Systems – In Assembly







Source: Matt Wallace and John McNamee, “Project Status”. 3rd Landing Site Workshop for the 2020 Mars Rover mission, Monrovia, CA, February 8-10, 2017

Before we talk about Planetary Protection, let's talk about microorganisms first!

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Mars 2020 Project

Oldest Form of Life: Micobes

Microbes isolated from deserts throughout the world.

Rio Tinto, Spain: a low pH, high heavy metal environment.

Live in harsh environments

H. pylori – causes ulcers. Tolerant to stomach acid.

Salmonella typhimurium (Food poisoning)- More virulent after growth in space!

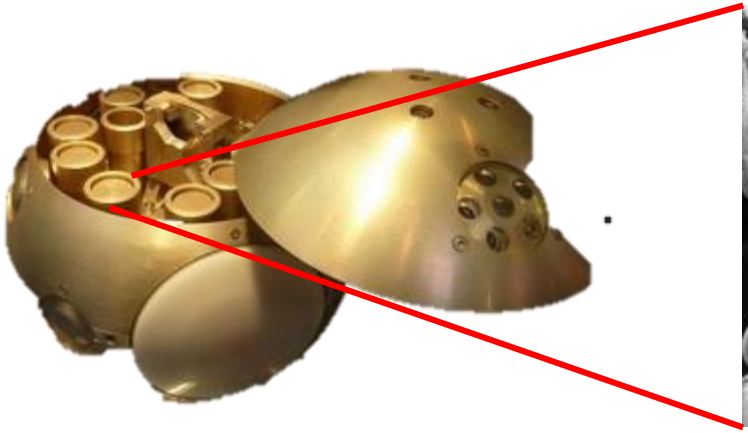
Have ecological impacts!

Humans are huge carriers of microbes!

Watney used his fellow Astronauts' fecal matter as fertilizer - Increased microbial biomass and diversity are beneficial to soil nutrient cycling.

What is Planetary Protection?

- Preserve planetary conditions for future biological and organic constituent exploration
  - *– Prevent forward contamination*
- To protect Earth and its biosphere from potential extraterrestrial sources of contamination
  - *– Prevent backward contamination*

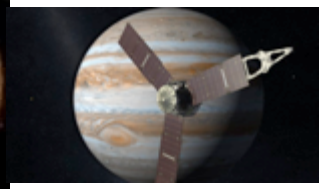


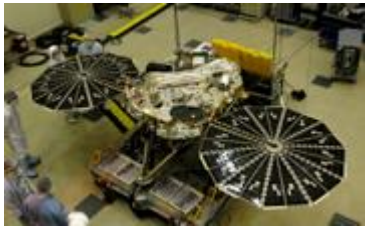
Planetary Protection is applied to many types of missions!

Depending on where you are going…

and what you are doing…


Fly-by


Orbiter


Lander


Rover

the Mission is assigned a Planetary Protection mission category which comes with cleanliness and documentation requirements.

Planetary Protection Categorization For Mars 2020

- Dec. 21, 2015 – PP Categorization of the Mars 2020 Mission
- Outbound - Category IVb-subsystem
  - Category IVb = Lander systems designed to investigate extant Martian life
- Inbound - Category V Restricted Earth Return
  - Category V Restricted Earth Return = the Earth return portion of a potential Mars Sample Return
- How does this translate into requirements?
  - This translates into extremely stringent cleaning, documentation, and review requirements to include reviews and approval 1) prior to launch from Earth; 2) prior to leaving Mars for return to Earth; and 3) prior to commitment to Earth reentry should NASA choose to bring the samples back.

Juno Under Construction

Cleaning hardware is easy, but keeping it clean…

Autoclave – 250°F

Humans contain $3x10^{13}$ human cells and $3.9x10^{13}$ microbes!

Viking Casserole: 248°F (120°C) for 54 hours

Bunny suits must be worn at all times around the spacecraft.

It takes a village - Mars 2020 Planetary Protection Team

Jet Propulsion Laboratory
California Institute of Technology

Mars 2020 Project

Moogega Stricker -
Lead

Brian Shirey -
Deputy Lead

Nick Benardini -
Group Supervisor

Gayane Kazarians

Parag Vaishampayan

Fei Chen

Heidi Aronson

Ryan Hendrickson

Raymond Ellyin

Kristina Stott

Kasthuri Venkateswaran

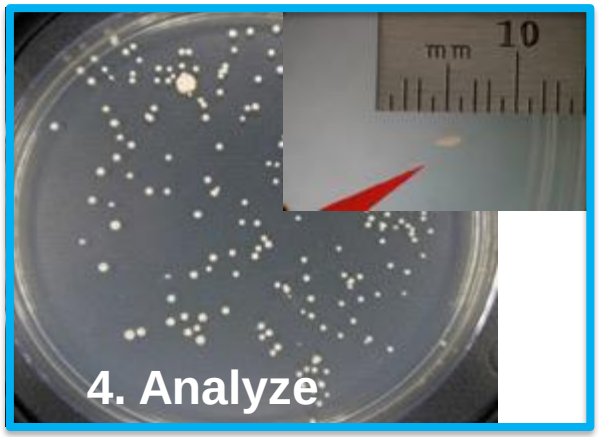
Not Pictured: -Wayne Schubert Arman Seuylemezian

General PP Implementation Approach – Clean, Cleaner, and Keeping it Cleaner

- The general approach to implementing heritage MSL-like PP for Mars 2020 mission consists of:
  - microbial burden reduction – processed controlled manufacturing, IPA, precision cleaning, ultra precision cleaning, 4-log heat microbial reduction (MSL 4-log 8020.12D, Mars 2020 4-log hardy spec) 6-log microbial reduction, ISO 5 assembly, aseptic and sterile assembly
  - sampling and bioassays – status, extensive microbial reduction process control sampling, closeout, last access and verification assays
  - re-contamination prevention – covering hardware while not in active use, proper bagging and packaging for storage and shipment, enhanced storage late integration, transport analysis to understand biological recontamination as it impacts engineering design and/or operations
  - exemption of accountable bioburden via HEPA filters and/or tortuous paths – rover warm electronics box, payload hardware, SCS sampling hardware
  - special cases (destructive assays for embedded bioburden assessment) drill embedded bioburden on seals, as necessary
- Tailored to specific hardware
  - design phase PP integration – embedded PP engineers on both the systems and SCS engineering team
  - the requirements of PP, in particular microbial bioburden requirements
  - the implementation feasibility
  - the assembly and integration details
  - minimization hardware manipulation and operations
- Flight spare(s) treated as flight units
- Archive
  - Spores© from the NASA Standard Assay
  - Metagenomic nucleic acid characterization to build a genetic inventory

Key
Mars 2020
MSL + Mars 2020

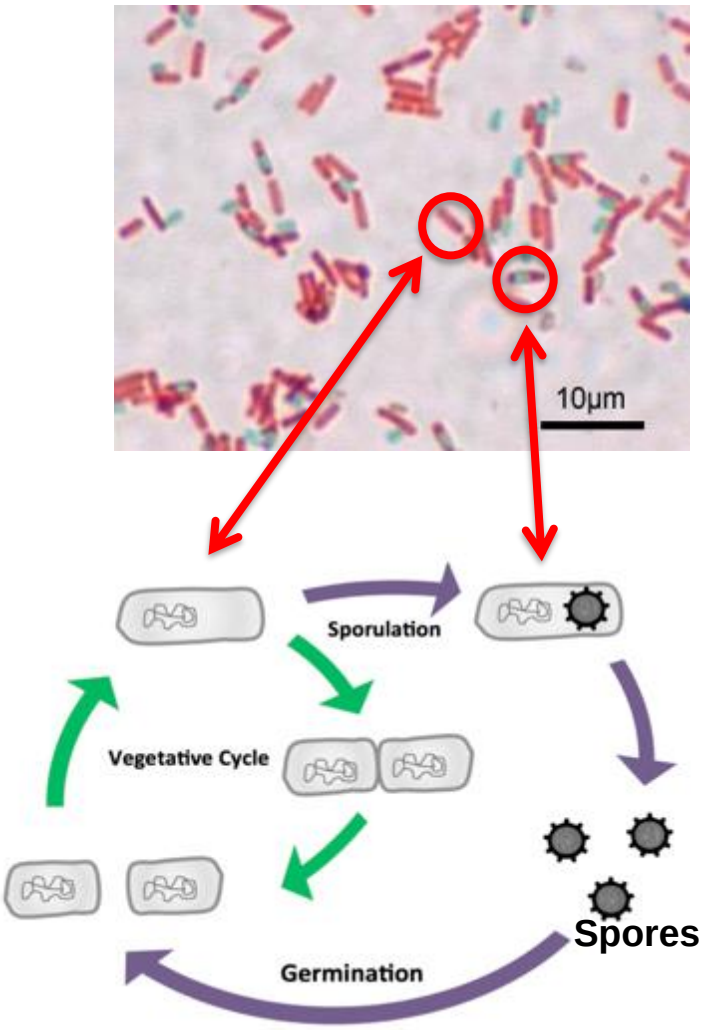
NASA Standard Assay Flow Diagram



- Sample hardware via Swab or Wipe (water is used as solvent)
- Process swabs and wipes using the NASA Standard Assay
- Analyze plates - count @ **24h, 48h, and 72h**

What Organisms We Worry About

- Planetary Protection is interested in contamination of microorganism structures called spores.
  - **Spore** - a structure formed by the actively growing stage of some bacteria.
    - able to remain viable under extremely harsh environmental conditions (e.g. heat, dryness, radiation)
    - when the environment improves, once again actively grows and proliferates
    - can remain dormant for up to 10 million years
    - Used as basis of PP requirements
    - We use the NASA Standard Assay to detect spores and to determine how clean a spacecraft is. “Assay or Bioassay”
  - Total Viable Organisms – The total amount of all types of microorganism (fungi, vegetative cells, spores, etc.)



Biological Requirements for Mars 2020

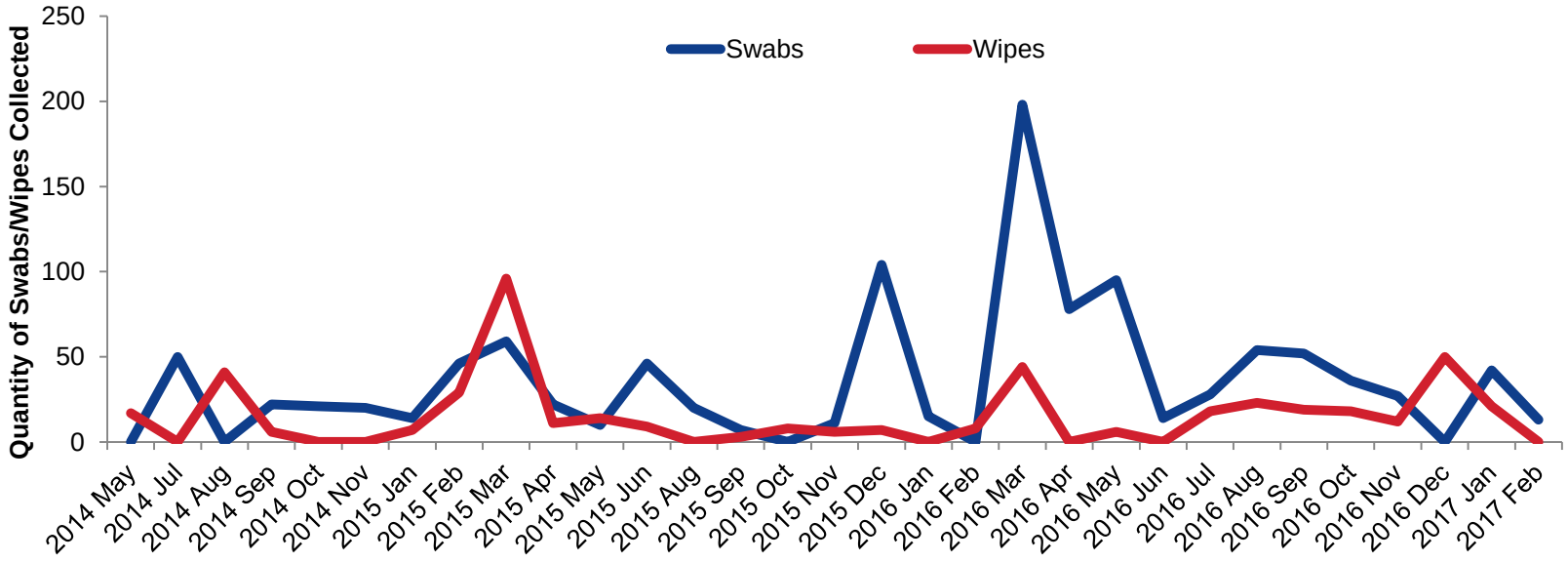
- Missions are designed so that their cleanliness is at a level where it will not interfere with the mission's science goals.
- Spacecraft shall not exceed the following bioburden requirements:
  - **Total bioburden** (surface, mated, and encapsulated) bioburden level is not to exceed to **5×10^5** spores upon launch
    - That's half the number of microorganisms on a square inch of human scalp – a small number for a rover with a total surface area larger than three basketball courts.
  - **Landed hardware** is not to exceed **3×10^5 spores** in total
    - Average of **300 spores/m^2**
- Probability of viable Earth organism in returned sample - The Mars 2020 Project shall be capable of encapsulating samples for return such that each sample in the returned sample set has more than a 99.9% probability of being free of any viable Earth-sourced organisms.
- Protection against false positive - The PS shall identify, quantify, document, and archive potential pre-launch terrestrial contamination sources, both organic compounds and organisms.

Mars 2020 Biological Assessment

- Many samples are taken in a launch campaign
  - Mars Polar Lander: more than 1200 samples
  - MER (2 Rovers): total of 3766 swab and 529 wipe samples
    - Approximately 35,000 petri dishes
  - MSL: 3472 swab and 1283 wipe samples (including controls)
    - 47,997 petri dishes

M2020 PP Hardware Sampling Status to date

- To date, we have processed
  - 478 Wipes
  - 1107 swabs
  - 155 air samples
  - 16633 petri dishes
- Trends demonstrate that sampling events have been increasing through time



Microbial Inventory Cataloging

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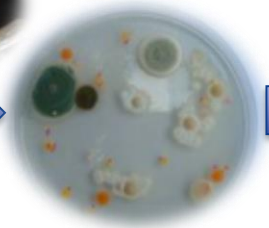
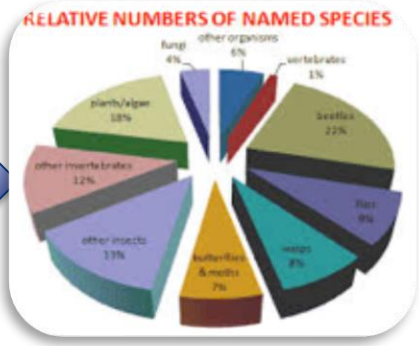
Mars 2020 Project

Grow



Identify



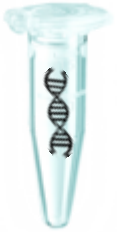
Arch

Traditional culturing takes >7 days to complete; Coverage is only <1 to 10%

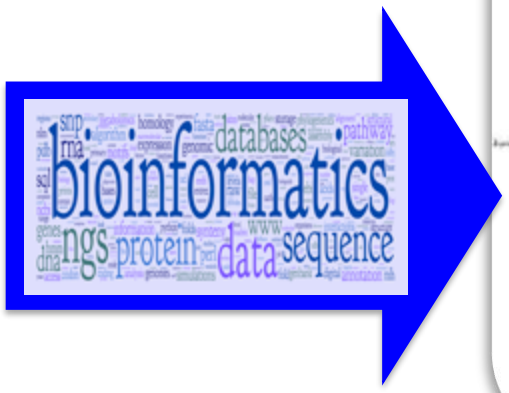
Molecular method takes <3 days to complete and yield ~>90-fold diversity

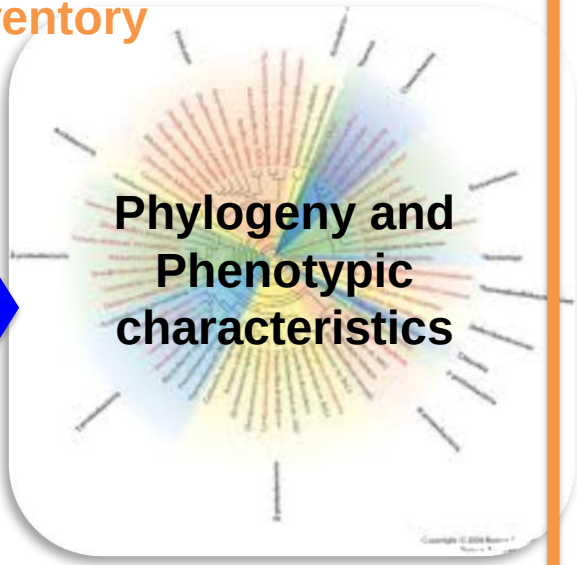
Analysis Pathway for Genetic Inventory

Archive



High Throughput sequencing





Microbial profiles in different clean rooms are different

1. It is well documented that the microbial profiles of geographically distinct cleanrooms are different (Moissel et al 2007, La Duc et al., 2009).
2. Cleanroom microbial profiles are influenced by external environment, cleaning protocols, maintenance practices, HEPA filtration system, Air circulation rate etc.
3. Hence, samples from all the clean rooms used during the course of spacecraft assembly should be collected.

TABLE 2. Bacterial OTU occurrence as a function of geographical sampling locations

Family[a]	No. of OTUs that can be detected by PhyloChip	No. of OTUs in clean room floors by facility type and sampling period							*P* value[b]
		PHSF			SAF				
		PHX-B	PHX-D1	PHX-A	MSL-B	MSL-D1	MSL-D2	MSL-D3	
Syntrophobacteraceae	35	8	7	8	7	4	3	2	0.04
Sphingomonadaceae	98	41	36	40	31	33	28	16	0.04
Sphingobacteriaceae	39	5	7	8	4	2	4	3	0.04
Shewanellaceae	5	5	5	5	3	1	2	0	0.01
Piscirickettsiaceae	28	4	4	4	3	2	3	1	0.04
Helicobacteraceae	64	23	21	25	22	14	11	9	0.04
Enterobacteriaceae	183	52	65	65	54	10	6	3	0.03
Coxiellaceae	15	5	4	5	3	4	2	1	0.04
Chromatiaceae	44	7	7	6	2	3	1	0	0.00
Caulobacteraceae	30	12	14	17	7	12	10	7	0.04
Burkholderiaceae	38	11	13	9	8	9	4	5	0.04

[a] Bacteria associated with aquatic environments.
[b] Differences between KSC and JPL facilities were considered significant at a *P* value of 0.05 (Student *t* test).

PP research contribution to the field of microbial ecology

1. We have submitted ~2000 16S rRNA gene sequences to public database (NCBI) from individual isolates collected from spacecraft and associated surfaces.
   - > 100 isolates are potential novel species.

2. We have submitted ~611K Bacterial, 110K Archaeal and 340K Fungal pyrosequences to public database.
   - ~10K sequences are unclassified and doesn't belong to known taxa.

3. We have submitted >1.5 billion metagenome sequences in public database.
   - ~100 million sequences are unclassified.

PP research at JPL has not only enriched our understanding of cleanroom bioburden but microbial ecology in general.

Project Summary and Conclusions

- Planetary Protection is a significant aspect to consider from design through implementation, launch, and surface operations.
- The mission design and implementation approach is fully responsive to meeting the project's requirements, to include biological cleanliness requirements
- The microbial ecology in the spacecraft assembly cleanroom is unique, at times resulting in discovering novel species.
- Lastly, and most importantly…

Let’s be good custodians of our universe!

Explore responsibly!